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Radiative transfer modelling for the NOMAD-UVIS instrument on the ExoMars Trace Gas Orbiter mission

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Abstract

The NOMAD (Nadir and Occultation for MArs Discovery) instrument is a 3-channel (2 IR, 1 UV/Vis) spectrometer due to fly on the 2016 ExoMars Trace Gas Orbiter mission. A radiative transfer model for Mars has been developed providing synthetic spectra to simulate observations of the UVIS channel in both solar occultation and nadir viewing geometries. This will allow for the characterization and mitigation of the influence of dust on retrievals of ozone abundance.

1. The UVIS instrument

UVIS is an ultraviolet and visible spectrometer forming part of the NOMAD instrument. UVIS will take frequent, high resolution (1 nm) spectra over the wavelength range of 200 - 650 nm (the model is currently running for 100 - 1100 nm). As a significant absorber of UV, determining the spatio-temporal distribution of ozone will assist in quantifying the amount of UV radiation reaching the surface, relevant for astrobiological studies of the surface environment. The instrument will also be used to investigate cloud properties, potentially differentiating between those composed of H_2O and CO_2 ice.

2. Rationale

Spectroscopy has been used to study atmospheric constituents for many decades. It is through this method that we learn the composition of non-terrestrial atmospheres. Numerous features of the atmosphere of Mars are not completely understood, particularly aerosols such as dust and ice cloud particles. The parameters describing the spatial, temporal, and size distribution of dust along with its composition require further investigation, although estimates have been made [1, 2]. Constraints on the values for the dust optical properties

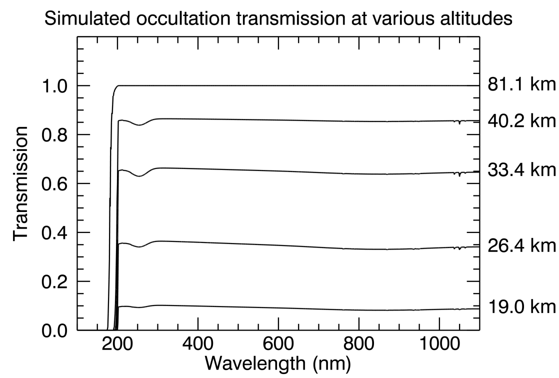

Figure 1: Example simulated solar occultation transmissions as the instrument field of view descends through the atmosphere. The modelled atmospheric vertical structure is from typical output of the Mars Climate Database [7]. Dust begins to have an effect below $\sim$ 50 km, and below $\sim$ 20 km transmission reduces to $< 10\%$. The 200 nm cut-off is due to CO_2 absorption, the 250 nm reduction due to O_3, allowing for retrievals of O_3 abundance.

of single scattering albedo and the asymmetry factor have been previously derived [3], although most investigations have addressed these parameters in the visible and IR wavelength ranges as opposed to UV. Better estimates of these parameters leads to better characterization of dust for global climate modelling and to a better understanding of dust composition, shape and population and so its role in the martian climate system. This would benefit future missions, for example through improved accuracy of aerobreaking calculations, and would allow for improved studies of the thermal role of airborne dust.

Another atmospheric constituent active at shorter wavelengths is ozone. It is known to some extent when and where ozone is found, but predictions do

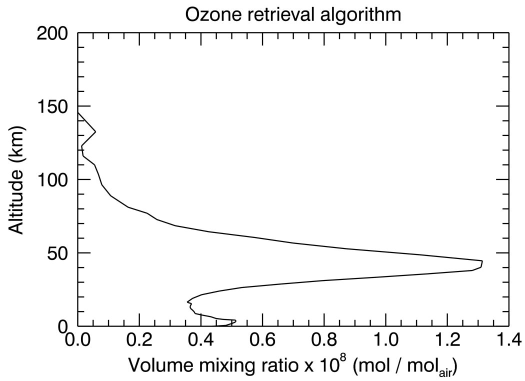

Figure 2: Example of a retrieval algorithm producing a vertical profile of O_3 abundance. Multiple occultations are used to invert O_3 slant densities. Work is being undertaken to optimize retrievals for high dust scenarios.

not always match observations [4, 5]. Measurements at higher sensitivity, coupled with analyses will continue to enhance our understanding of how ozone behaves on Mars. This will expand the spatial and temporal data set to enable further study of the response of ozone to diurnal, annual and compositional variations within the atmosphere.

3. The model

The model being used is NEMESIS [6], a general-purpose retrieval model originally developed for the composite infrared spectrometer on board the NASA Cassini mission. NEMESIS can be used for a general atmosphere, and has been deployed here for martian atmospheric conditions, including using updated dust optical properties [3], and extended to cover gaseous absorption in the UV wavelength range. Figure 1 shows how simulated transmission spectra change during multiple occultations as the field of view descends towards the surface. There is a reduction in transmission as the path length and atmospheric density both increase. One outcome of this work is to determine the minimum observational altitude during various scenarios, expected to be at approximately 20 km.

Vertical profiles of ozone can be retrieved by using many occultation transmission spectra to invert ozone slant densities. Figure 2 shows an example of such a retrieval, recovered from 50 simulated transmission spectra of a typical Mars Climate Database atmosphere.

4. Summary

Work is ongoing to maximize the scientific output of the future mission data with particular emphasis on the detection of trace gases including O_3 and potentially SO_2. Assessing the impact of variations in the properties and distribution of airborne dust on retrievals forms a major part of this study.

Acknowledgements

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